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SPACE: INDUSTRY OF RESEARCH AND FLIGHTS

R. Svoren'

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16. Abstract

A popularized-science account of typical papers read at the 24th International Astronautics Congress held in Baku. Interviews with the Federation's president, and Soviet and American scientists are presented.

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SPACE: INDUSTRY OF RESEARCH AND FLIGHTS
Report from the XXIV International Astronautics Congress
by special correspondent of Nauka i Zhizn', R. Svoren'.

R. Svoren'

Nearly a quarter century ago -- in 1950 -- several groups of /16* dreamers, enthusiasts in astronautics, formed the International Astronautics Federation and held its first congress. In addition to discussing problems of organization and founding, several papers on the essence of the problem were read at the congress. They all, of course, dealt with what was desired to be done; the subject matter was, as a rule, in the subjunctive mood -- "if ...," and the papers themselves, the speakers, and even the entire congress in general went practically unnoticed and did not attract public attention. Who then could know that very soon the crazy ideas of space flights would put into motion gigantic scientific and industrial complexes, that beneath enormous sensational headlines they would appear on the first pages of all the newspapers in the world. Who could know that even in some 7 years the first satellite would be launched. That after it would follow one after the other -- Lunniki, Lunokhody, the automatic stations in the sky Venera and Mars, manned space flight, the penetration of outer space, people on the Moon, space weather stations and great orbital laboratories where man could work for a month, or two, ...

The first astronautical congress was held in London. Then came Athens, Stockholm, Belgrade, Vienna, Rome, Paris ... And now Baku -- a warm, hospitable enormous city. The congress became for Baku residents "event number one," a responsible and grand examination in hospitality. Motorcycle escorts accompanied the buses of congress participants; with the solemn fanfare of

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* Numbers in the margin indicate pagination in the foreign text.

orchestras they were greeted at the legendary Neftyanyye Kamni, Pioneers in white holiday dress scattered flowers along the mountain road to Shemakha Observatory. Crowds of people waited for hours at hotels in order to see the cosmonauts -- our V. Shatalov, G. Beregovoy, and V. Sevast'yanov, and the American P. Stafford, and when a person bearing the large blue button of a congress participant simply came out to walk along the noisy Baku streets, at once he became the center of attention -- he was smiled at, waved at in greeting, and made room for.

The work of the congress, as a rule, took place simultaneously in six halls in three different districts of the city. This, in particular, determined the pace of work of the large army of journalists who had come for the congress, including foreign journalists (many of whom call themselves "space-reporters," (reporters of space subjects). By continuously leafing through the program and making notes of exceptional events in it, which soon became indecipherable, we vigorously and randomly, as particles in Brownian motion, shifted from one paper to the other, from one discussion to the other.

5000 "Zhiguli" in Space

In attempting to sum up everything that it was possible to see and hear, and to formulate one's main impressions of the congress, you remember that it showed the most, evidently, typical features of modern astronautics. In particular, such as the following:

the broad scope of investigations and their industrialized character. Illustration: as of 1 July 1973 in the Soviet Union along 742 craft had been launched into space orbits. Their total weight was 2233 tons. Considering the final stages of launch vehicles placed in orbit, the total weight of the space cargo was 4388 tons, and this is nearly 5000 Zhiguli. Imagine the picture -- for 10 days in a row, all the vehicles from one of the gigantic conveyors of the VAZ [transliterated name of new automotive plant] head straight into orbit ...

complexity and high advancement of equipment. Illustration number one: during the flight of the Luna 16 Automatic Station, returning samples of lunar soil to Earth, its automatic devices independently performed hundreds of operations of control, monitoring and correction; the equipment included in this system contains many thousands of electronic parts. Illustration two: in photographs of regions of the city of Chicago taken by American specialists from space, seven to eight million individual details can be distinguished.

complexity of tasks and high precision of their performance. Illustration: in several cases, for the exact determination of the satellite orbit, among the numerous other factors account is taken of the force of recoil that the craft experiences at the moment it sends radio waves by its onboard transmitter. This is approximately the same as taking account of the recoil due to the radiation of sound waves that a steamship experiences when one of its passengers, standing on deck, converses in a whisper.

broad scope of problems. This feature can be illustrated by /17
a short list of the papers and reports among those given at the congress:

"Optimal Control of Spacecraft in Successive Aero- and Rocket-Dynamic Deceleration in the Martian Atmosphere."

"Cost Problems in Designing Space Shuttles."

"Legal Problems in the Mastery of the Moon and Other Celestial Bodies."

"Plasma Propulsor With Metal Reaction Mass"

"Effect of French Space Program on Advances in Technology"

"Psychological Model of Reduced Gravity"

"Equations of Perturbations for Flexible Satellites"

"Compatibility of Spacecraft"

"Radiation Shelter for Prolonged Flight"

"Optimal Trajectories of Probe for Searching for Extraterrestrial Civilizations"

"Role of the United Nations in the Utilization of Space"

"Effect of the Atmosphere on the Spectral Brightness Values of Natural Formations"

"Interstellar Relativistic Rocket Trajectories with Restricted Thrust and Acceleration"

"Air and Space Piracy"

"Satellite with a Nuclear Powerplant"

"Postal Rocket Building in Yugoslavia"

"Water-Oxidizing Bacteria as a Promising Protein Producer for Life Support Systems"

"From the History of Building of First Artificial Earth Satellite"

"Rescue of Crews After Their Forced Grounding in Uninhabited Localities"

"Use of Satellites for Observations of Aviation and Marine Communications"

"Use of Radio-Interferometry in International Investigations of the Mechanisms of Earthquakes"

"Safety Techniques When Working with Teenagers in Rocket and Space Modelling"

"Investigation of Secondary-Electronic Discharge on the 'Salyut' Station"

"Reservoirs with Capillary Filling for Rocket Fuel"

"Draft Convention on the Moon"

"Scattering of Light by Spacecraft as Interference in Astronomical Observations"

"Results of the Flight of the Yantar'-4 Ionospheric Laboratory"

"Optimal Entry Trajectories into the Atmosphere"

"Apollo Space Telescope on Skylab"

"Assimilation of Atmospheric Nitrogen by Living Organisms"

"Problems of Building Venera Landing Craft"

"Analysis of Rocket Designs Described in Works of the XVI-XVII Centuries"

"Studies of Lunar Craft"

"New Forms of Wings for Hypersonic Flights"

To this list must be added the fact that many subject-area sections were held at the congress ("Astrodynamics," "Processes in Jet Engines," "Space Law," "Bioastronautics," "Space Transport," and another approximately 15 others); about 300 papers were read; several special symposia and discussions were held, in particular on an international laboratory on Mars, an international orbital laboratory, and on the upper atmosphere (the effect of flights on the composition of the stratosphere).

And, finally, one more feature of today's astronautics; it more than all the others was sensed in the work of the Baku congress.

Of course it is worth dwelling on this in more detail. We begin with a somewhat more detailed familiarization with several problems discussed in Baku, taking a look at papers read at the congress, and talking with its participants.

First of all, about the great hopes that specialists are now placing on satellites rotating

Around the Mysterious Planet

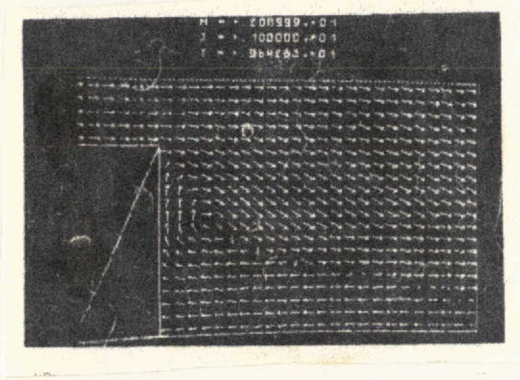
In this name -- "mysterious planet" -- which our Earth is often called in popular science books, there is no overstatement. One can hardly maintain that, by coloring white spaces on geography maps we would already recognize our home, our Earth. How do cyclones form in the ocean? What lies beneath the thin layer of the Earth's crust? How does the dust content of the atmosphere change and how does it affect climate? How severely contaminated is the World Ocean? To what biological consequences will this contamination lead? Where, when and how do forest fires start?

What are the total reserves of natural resources needed by man? Where are they hidden? There are thousands of these questions. A space patrol -- satellites and orbital laboratories which can for months and years hang over the planet "free" can help in answering them. It is not mere coincidence that the present stage of development in astronautics is most often called the epoch of orbital stations.

K. Kondrat'yev, G. Beregovoy, A. Buznikov, O. Vasil'yev, A. Grigor'yev, A. Nikolayev, V. Sevast'yanov, O. Smoktii, Ye. Khrunov, and V. Shatalov (USSR). "Man and His Environment: Remote Sensing from Space" (abstract of paper).

In a number of scientific studies in recent years one can find warnings about the dangers associated with the contamination of the environment and the depletion of natural resources that are encroaching on mankind. However, one of the weak points of these warning predictions and recommendations that follow from them is the absence of many important data about the actual state of the environment. In the scale of the planet these data, as well as a global estimate of natural resources, can actually be obtained by only one method -- from the orbit of an artificial earth satellite. Advantages: coverage of the entire globe, speed, responsiveness, possibility of reacquisition of data, and qualitatively new information (for example, on the macrostructure of cloud formations or on planetary tectonic structures).

Over the last decade, regular and systematic experiments on remote space sensing have been conducted in the USSR, and Soviet scientists have made an important contribution to developing space geography. During the flight of Soyuz 7 (1969), for the first time space, aircraft and ground observations of typical sections of land and sea were made -- key sections that can serve as reference standards in interpreting space observations. A complicated problem of determined the so-called transfer function of /18



The birth of a new spacecraft is a complicated process. And along the entire route from the first idea to the first launch, a large and complex industry of mock-up construction, checking and tests participates in it. This figures illustrates the wholly new possibilities that modern computers open up in this field. On the screen of an electronic computer we can see the picture of the behavior of a gas jet flowing past an obstacle, calculated by the computer. Even though the system does not replace the wind tunnel, it greatly economizes the time and funds needed for "blowing" past numerous intermediate models in a wind tunnel.

O. Velotserkovskiy and Yu. Davydov (USSR). Numerical experiment in the study of gas-dynamic characteristics of flow past bodies (illustration for paper).

the atmosphere is being solved, making it possible to cancel out the effect of the atmosphere on observational results. Several promising methods have been found, such as, for example, recording the spectra of the twilight halo of the Earth that permits estimating the dust content of the atmosphere, the blowing off of the surface layer of soil, volcanic activity, and industrial contamination of the air. The method is very important for estimating the thermal regime of the Earth and possible climatic changes.

Among the urgent problems are these: interpretation of images of the Earth in different spectral regions; using radar for probing the atmosphere and the underlying surface (there has been successful experimentation done on the Kosmos 243 and Nimbus 5 satellites); spectral photometry of the horizon to analyze the distribution of the atmospheric aerosol (the problem of man's effect on climate); long-term measurements of the solar constant (the problem of the effect of solar activity on weather); further study of the possibilities of sensing the state of plant cover, soil properties, snow and ice cover, cloud cover forms, and so on; comparison of the possibilities of various types of orbital craft for space sensing; and study of the prospects of building a lunar observatory to study the Earth.

The diversity of the problems indicates that this problem area is in the experimental stage of exploratory development and that coordination of efforts from different countries in performing these missions is vital.

A brief interview with Professor R. Moore (USA) acquainted us with yet another possibility of studying Earth from space. His account can be called

Space Radar

"At this congress, Professor, you presented a paper on measuring the wind velocity at the very surface of the Earth from orbital stations ... Can you explain, please, even though in the most general way, how it is possible to measure the wind velocity while being at an altitude of several hundred kilometers ..."

"First of all, a very minor correction ... I was speaking about measuring the wind velocity not in the Earth in general, but over the surface of seas and oceans. These are the most important regions, incidentally, for meteorologists. And at the same time it is expensive and difficult to organize a network of weather stations in the ocean.

"Now about the essentials of the method. In addition to the well known large waves, over the surface of water pass small waves several millimeters high. These are the ripples produced by the wind. The parameters of these ripples -- velocity, "crest" height, distance between crests and others -- depend on wind velocity. If one directs at the water surface a radio beam, and then receives and analyzes the signal reflected from the water, then from several characteristics of this reflected signal one can estimate the condition of the "mirror." One can also estimate the direction and velocity of the wind producing the ripples on the water. As you can see, traditional methods of radar are used to measure wind velocity."

"It seems that everything is quite simple ..."

"Oh, this is only at first glance. The actual electronic equipment for these measurements is quite complicated. Especially the section that scrupulously analyzes the signal reflected from the water and literally drags out of it information about the condition of the sea surface."

"Has your method undergone practical tests?"

"Yes, it has. In particular, on Skylab."

"And what have been the results?"

"Measurements taken by the second station crew are still being studied. The results of the measurements by the first crew are quite satisfactory."

"To what precision was the wind velocity of the ocean measured from onboard the orbital station?"

"In order to determine this, one would have to make a fairly large series of control measurements simultaneously in the sky and at the water itself. Thus far this has not been done. But I think that the error does not exceed plus-minus ten percent."

"How do you, Professor, see the practical application of the method in the foreseeable future?"

"I believe that a network of space stations must be built, more likely an international network, that will with radar methods measure the velocity of air masses in all regions of the World Ocean. This will only be one of many jobs of space radar. Its capabilities in studying the Earth from space are enormous. I am confident that even in obtaining "pictures" of a particular section of the Earth, radar methods (radar specialists have long been able to obtain "radio pictures", photographs of a local made with a narrowly directed radio beam of a radar probing the Earth point by point) will successfully compete with photography in terms of information content. Without even speaking of the interpretation of a signal reflected from the Earth, about the extract of useful information that is contained in particular signal parameters, the capabilities of radio electronics are truly fantastic."

Man receives electromagnetic waves (sees) in a relatively narrow spectrum of wavelenths -- approximately from 4000 to 7000 Å. /19 Evolution, as always, dealt wisely -- this range is most necessary to us, for in this range the sun glows or shines the brightest. But reason created by evolution proved to be smarter than evolution. We learned to see the invisible, to see pictures produced by waves that are shorter than light (ultraviolet, gamma-rays, X-ray radiation) and waves that are longer (infrared rays, radio waves). Today from the altitude of space orbits,

By Looking at the Invisible,

specialists have obtained new interesting capabilities of studying out planet.

V. Artemov, A. Basharinov, L. Borodin, V. Bulatnikov, S. Yegorov, V. Mishenev (USSR). "Radio Brightness Characteristics of Several Natural Formations." (abstract of paper).

In the summer of 1972, the intensity of radio emission (radio brightness) of burning zones of peat beds and forests was investigated from low altitudes. The wavelength was 8 mm, the directivity of the antenna "probing" the Earth was 1°. It was found that the temperature of burning stalks of peat exceeded the temperature of the underlying surface by 300°, the burning peat swamps -- by 400°, and the unburning stems -- by 50-70°. The "mosaic" structure of forest fires was detected; sections with intense burning alternated with sections at low temperatures. The measurement of radio brightness makes it possible beneath the cloud layer, beneath the layer of dust, to detect sections of a burning forest, swamps and peat workings, and to find sections with critical heating.

A. Basharinov, L. Mitnik, M. Krylova, N. Kukharskaya, and A. Tsvetkov (USSR). "Probing of the Cloud Atmosphere in the Microwave Range." (abstract of paper)

By measuring the radio brightness of clouds at three points of the spectrum, on can determine the total mass of water vapor in the atmosphere, the water reserve and the effective structure of clouds, and also determine the vertical profile of temperature and humidity. The capabilities of measuring the brightness of IR (infrared) radiation to solve these problems are very limited owing to the intense absorption of IR rays in clouds.

V. Lapshin, G. Lebedeva, and B. Nelepo (USSR). "Problems of Space Sensing of Contamination in the Ocean" (abstract of a paper).

Investigations have been made of electrical characteristics of ocean water covered by petroleum. It was shown that measurements of radio brightness taken from a satellite not only detected contaminated ocean areas, but also provided an evaluation of the nature of the contamination and its concentration.

"The time will come, and we will hold our congress in orbit," joked Prof. Luigi Napolitano, president of the International Astronautics Federation. But in this joke, just as in any others, there is a grain of truth. It may be that even more so than in any other.

In his address to the congress participants in Baku, Prof. L. Napolitano wrote: "The unchanging concern of the International Astronautics Federation for the universal dissemination of knowledge acquired in astronautics prompted the theme of the present congress: 'Space Research: Effect on Science and Technology.'"

And further: "No better theme could be found for a congress held in the Soviet Union. From the first pioneering work by Konstantine Eduardovich Tsiolkovskiy (1857-1935) at the dawn of the space age to the flight of the first cosmonaut Yuriy Alekseyevich Gagarin on 12 April 1961, beginning the space age; from the many scientific and technical advancements achieved since then to the continuous and constant participation in all fields of research and peaceful utilization of space in our time, Soviet scientists, engineers and cosmonauts have given many important example of the effect of investigating space on science and technology.

"I am confident that this congress held in the Soviet Union will be a large step forward in achieving the well-being of mankind in the spirit of friendly and constructive international cooperation.

In addition to studing the natural environment, there is one more region in which space provides effective assistance to Earth -- the achievements of advanced space technology are being transferred to other areas. At the same time, technological processes are under development that are best performed in space. The time will come and

The Sum of Space Technologies

will take its place on the gigantic conveyor of Earth production.

B. Paton (USSR). "Problems of Space Technology and Their Effect on Science and Technology" (abstract of paper).

Today no longer does anyone doubt

that in the near future many technological operations will be conducted in space, for example, in building large orbital stations or in production sections of transport into orbit. Among these operations are welding and melting of metals.

The heightened interest of technologists in the melting of metal in space is associated with the space conditions that are nonreproducible on Earth. Such is the following:

weightlessness (absence of convection, buoyance, and other phenomena associated with differences in the density of materials);

deep vacuum and the associated very high rate of "evacuation" of vapor and gases from the working zone; and

the broad range of temperatures in which a molten metal can remain for a long time.

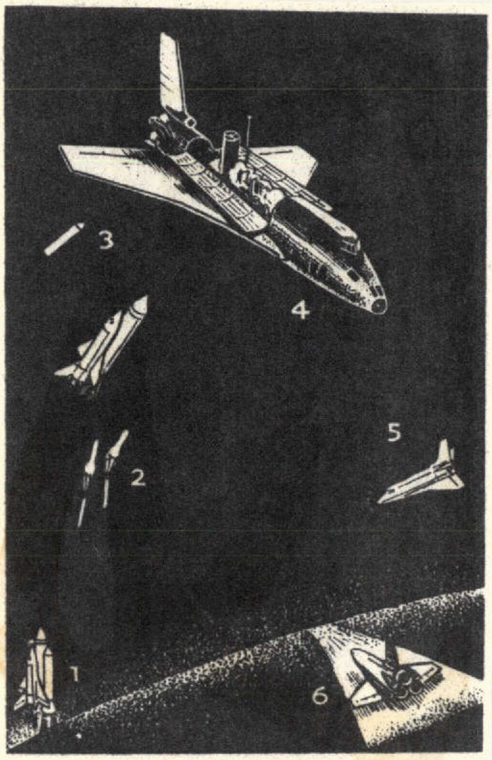
It is necessary to carefully study the behavior of molten metal in these conditions, in particular, to study the following: the processes of its cooling and crystallization both in the free state as well as at forced heat removal; the separation of phases (liquid, gas and solid phase); the action of forces of surface tension; and the wettability for different combination of phase and material.

At the same time, it is necessary also to study the physiological capabilities of man in performing operations in space such as welding, assembly of metal structures, melting of metals, finishing of openings, clearances and butt connections. It is /20
well-known that conducting each experiment in space requires great outlays. Therefore, it is best that all the initial developments be conducted on Earth using space condition simulators.

To study technological processes in conditions simulating weightlessness, we built a flying laboratory on board an aircraft.

Among other studies in this laboratory, the effect of short-term weightlessness on various methods of heating metals was investigated -- plasma, electron beam, and arc, with helium welding and others. It was found, in particular, that molten metal, if it satisfactorily wets the walls of the mold, during weightlessness easily rolls along the walls; with poor wetting, the metal collects into a drop, which leaves the mold, probably under the effect of an electrostatic field. Welded joints made in weightlessness and on Earth are generally identical, though in some conditions more porous joints and a specific microstructure of the remelted metal are obtained in weightlessness.

The first experiment on welding and cutting of metals in space was done by the pilot-cosmonauts V. Kubasov and G. Shonin on Soyuz 6 in 1969. The American astronauts conducted experiments on welding and melting of metals on board Skylab in the summer of 1973. In experiments on Soyuz 6 the Vulkan unit was used (total weight 50 kg), including a unit for three kinds of welding -- electron beam, compressed arc and fusible electrode. In developing the equipment, fundamentally new technical solutions were found, which subsequently were the basis of designing powerful small-scale accelerators. (In the near future, incidentally, it is planned to conduct a joint Soviet-French Araks experiments where these accelerators will "inject" powerful electron beams into the atmosphere at high altitudes.) Also found were new methods of soldering, welding and cutting of metals that have already been applied in Earth metal-working industry. In several industrial sectors, in particular in radio electronics, equipment that embodies many technical solutions has found application, and therefore also the high qualities of space equipment for hot



After launch (1), the space shuttle first ejects the first-stage fuel tanks emptied by the engine (2), and then the second-stage (3) makes a many-day long orbital flight (4), enters the atmosphere (5), and lands "like an airplane" (6). This scheme of orbital flights has captured the closest attention of specialists; in a number of countries, a major portion of space budgets, and much scientific and design effort is being invested in its realization.

J.-P. Koss (France), Space Laboratory (illustration for paper).

working of metals (high reliability and safety; small size and weight, low power consumption; operation in deep vacuum). If it proves possible to reduce the cost of this equipment, it will find wide use in many industries on Earth.

Space investigations have provided a powerful impetus to investigations in welding and metallurgy. Today the first tests of new efficient technological processes and reliable small-scale equipment are being completed both in our country as well as, judging from press reports, in the United States. Evidently, in the near future we must expect new experiments in metallurgy, welding and cutting that are already of practical importance both for space flights as well as in producing new materials. (Among the articles which in the future can be made in orbital laboratories we must mentioned first of all various composite materials based on light alloys reinforced with high-strength filaments or "whiskers;" foam metals marked by strength, lightness and low thermal conductivity; monocrystals for the electronic industry with properties that are unattainable for Earth production; and certain kinds of castings.)

In addition to this, already our main task is being successfully performed -- the achievements of space equipment and technology are being used to the maximum to increase man's well-being on Earth.

Weightlessness cannot affect forces with which electric and magnetic fields act, nor can it influence the work that they can do. And it is wholly probable that in spacecraft of the future, electric and magnetic fields will play a vital role in technological equipment in orbital factories, replacing Earth gravity. And sometime it may be a means of doing in space what is impossible on Earth. Acting, finally, independently

Without This Interfering Gravity.

I. Kirko (USSR). "Magnetic and Electric Fields as Structural Elements in Orbit" (abstract of paper).

Calculations of experiments show that an electric field can completely separate the liquid phase of a material (for example, fuel) from the gaseous phase in large tanks, which in conditions of weightlessness is a very complicated problem. In small vessels, the separation of phases occurs in crossed electric and magnetic fields. The "capillary game of ball" evidently is electrical in nature, when due to the reserve of surface energy a drop of mercury leaps up when entering the state of weightlessness, and /21
then recoils from the interface of liquid-air.

A spherical wall-less basin produced in weightlessness with the electric field of a spherical capacitor can serve as a reservoir for melting or storing liquid metal at temperatures of

The attention of the press to a scientist always reflects the interest of the broad public in his scientific problems. Professor I. Shklovskiy (USSR), director of the astrophysics division of the Institute of Space Research (upper left photo), Professor W. Pickering (USA), head of the largest space amalgamation, Jet Propulsion Laboratory (right photo), and Professor S. Mandel'shtam (USSR), scientific director for the Soviet side of several Interkosmos programs (lower left photo) respond to questions from correspondents.

2000°-3000°C, as well as the design basis for a fast neutron reactor. Using electric and magnetic fields, wall-less tubing can be constructed. One can imagine a powerful orbital atomic power station (wall-less reactor, wall-less basin or the heat carrier -- molten metal), which with a narrowly directed beam of centimeter radio waves transmits electric power to Earth.

The contribution of astronautics to our earthly life is not only the solution of practical problems of the present day. Astronautics is already working on tomorrow, assisting in achieving the product of greatest value to man -- knowledge. Already many times men have been sent into space

In Expeditions Seeking Knowledge

and have always returned with a rich harvest. Several features of one of these future experiments were touched on in an interview by the magazine's correspondent with Professor E. Stulinger, scientific director of the Marshall Space Research Center (United States).

"Periodically accounts have appeared in the world press about manned flight programs to Mars. Can you, Professor, comment on these programs ..."

"Unfortunately, I cannot. And only because, I hope, for a very valid reason: there are no well-detailed or, even less so, coordinated and confirmed plans of this kind, as yet. There are only several ideas, mainly of a personal nature."

"Then, if this is possible, can you tell us, please, how you imagine a Martian expedition in these "personal ideas." Above all, in your own ... when, how and from where will man fly to Mars?"

"Today there are no longer any fundamental obstacles to be seen preventing such expeditions, but there are no small number of specific engineering problems that are simply physically not possible to solve at once. This involves, for example, power engineering -- it is evidently necessary to have new engines -- nuclear, ionic -- of which at this congress we can as yet speak only in the future tense. It is probably necessary to pass through

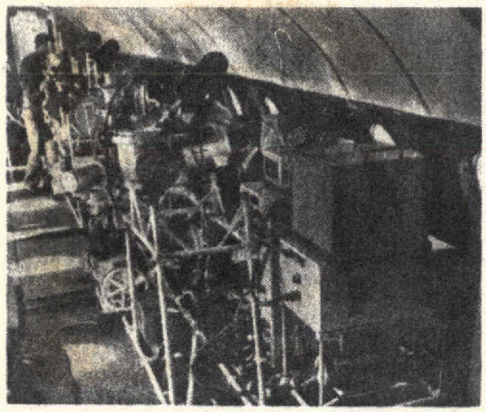
the epoch of large prefabricated orbital space stations from which Mars flights can be launched. It is necessary to build large spacecraft with artificial gravity. I believe that this will be simpler than remaking human nature. The problem is that after extended residence in weightlessness (and this, in particular, has been confirmed by the Skylab experiment) astronauts must be in special conditions, at complete rest, under physicians' observa- /22
tion. But, on arriving at Mars after an eight-month flight, cosmonauts will not be able to count on a sanitorium; they must at once begin their by no means easy work. There are also other problems associated with human nature itself, for example, protection against radiation. And, finally, there is the problem of reliability, which evidently needs no comment. I believe that one of its solutions will be the fact that not one spacecraft, but two ships at the same time will fly to Mars, capable when necessary of helping each other. Or even three, four craft ..."

"In a word, a veritable Martian squadron...."

"But even automatic stations usually fly to Mars in these squadrons, as if backing up each other. True, not for mutual assistance, but because craft cannot be launched toward Mars whenever one thinks it time to do so. This can be done, as we know, only once every two years ... Our Mariner 6 and Mariner 7 were launched together toward Mars, followed by Mariner 8 and Mariner 9 and the Soviet Mars 2 and Mars 3. And, finally, today the largest squadron of four Soviet Mars craft is on its way, launched in the last suitable "window" in the summer of 1973."

"Incidentally, why did the Americans let this "window" slip by without launching a single craft towards Mars this time?"

"The answer will be very short: money. We do not have enough appropriations. This is incomprehensible to you? To me as well ..."



Before technological equipment goes into space orbit, it passes through a large complex of tests in a flying laboratory on an aircraft.

B. Paton, D. Dudko, V. Bernadskiy, V. Lanchinskiy V. Stesin, A. Zagrebel'nyy, and O. Tsygankov (USSR). Stands for Investigating Technological Processes in Conditions Simulating Space. (illustration to paper)

"Recently one has been hearing more and more about space research with the joint efforts of different countries. And this is understandable: these investigations are a costly undertaking; it is simpler to do much "pooling together." But even if the financial side be sidestepped, there remains the purely scientific, that is, association, that will doubtless accelerate the realization of great plans. We have already, incidentally, had good experience in working with Soviet colleagues, reflected in the multi-volume joint work on space biology and medicine. In the near future there lies the joint flight of Apollo and Soyuz. One would wish that also to Mars our ships would fly together as part of a large Martian squadron ... "

The long many-month and then many-year flights of man to other planets will require not only the solution of tremendous technical and organizational problems. Biologists and doctors must also give their "okay" to these flights. Accordingly, for them scientific work in which

Immobility Is Being Investigated

is now of great interest to them.

Hypokinesia (or hypodynamia), that is, sharply reduced activity that can be investigated in Earth conditions is directly associated with residence in weightlessness, and with the absence of gravity loads on an organism, on living structures.

S. Baran'skiy, V. Baran'ska, and M. Kuyava (Polish People's Republic), "Effect of Prolonged Hypokinesia and Physical Load on the Function and Morphology of the Myocardium" (abstract of paper).

Studies have been conducted at the Military Institute of Aviation Medicine and the Institute of Biological Studies, Medical Academy, Warsaw. The subjects of the investigation were three groups of male water rats, 30 in each group: the control group, a group which for 6-7 months remained in conditions of severely restricted movement, and the group which after the regimen was subjected to a measured physical load -- 1-2 hours of swimming. In earlier, similar experiments serious morphological changes were observed in certain muscles and a decrease in the speed of nerve impulse transmission. In the latest experiments, a decrease of "cell fuel" -- glycogen -- in myocardial cells was observed, especially after physical load. An acute decrease was also observed in the chemical activity of one of the enzymes -- succinic acid dehydrogenase -- which at present is difficult to explain. Destruction of the internal structure of certain mitochondria in areas which are far from arteries and poorly supplied with oxygen was observed as well.

However, cardiogram analysis, microscopic tissue examination, and biochemical tests show that during hypokinesia, the organism carefully protects the heart muscle, possibly even sacrificing other tissue. However, it cannot protect the heart from the severe result of abrupt activity after a long intermission.

B. Fedorov (USSR). "Effect of Decrease in Muscular Activity on the Cardiovascular System -- An Urgent Problem in Modern Medicine" (abstract of paper).

A decrease in motor activity characteristic of much of the population in highly developed countries is an important factor in the growth of cardiovascular disorders. In studying the problem, the principles of humaneness severely limit the possibility of experimenting on man. The paper reports on a series of experiments on 350 rabbits conducted at the Institute of Medico-Biological Problems, USSR Ministry of Public Health. Once again it was confirmed that a decrease in motor activity leads to the most serious shifts in the organism, in particular, in the system of neural regulation of blood circulation; in the system of hormonal metabolism (the activity of the cortex of the adrenals and the thyroid gland is severely decreased; in particular, even after a month of confinement, the adrenalin level in the adrenal cortex dropped from 240 μg/g to 90 μg/g, that is, by 2.5 times); in the myocardium (muscle fibers are destroyed and the structure of the mitochondria is altered). In these conditions, earlier easily tolerated loads become excessive; stress is produced; the organism become predisposed to crisis phenomena and to a disruption in /23
adaptive reactions.

Qualitative and especially quantitative conclusions from similar studies can serve as a basis for practical recommendations on the regimen of cosmonauts in extended interplanetary flights.

Among the scientific research performed with spacecraft, there are also studies that can shed light on the most profound secrets of nature. One of the organizers of a symposium on the problems of the theory of relativity in space, Doctor of Physico-Mathematical Sciences V. B. Braginskiy, professor at Moscow University, spoke about how

Astronautics Helps in Understanding How the Universe Was Constructed.

"Please explain, Vladimir Borisovich, why at an astronautics congress a symposium is held on so specialized a subject of physics, and what raises the mutual interest of specialists in cosmonautics and relativity theory ..."

"At the outset, one must add the qualification that the reciprocity here is still very asymmetric -- the theory of relativity has only begun to function in the practice of space navigation. It is becoming a necessary working tool in distant interplanetary and interstellar flights, for velocities of spacecraft that are commensurable with the speed of light. In these case, in particular, relativistic corrections to the classical calculations of trajectories or corrective actions will prove already so large that specialists in astronavigation will simply not be able to cope without GTR, without the general theory of relativity. In the same fashion, let us say, as today the builders of atomic reactors or accelerators cannot cope without the special theory of relativity.

"On the interest of physicists in astronautics, it is associated with the new possibilities of conducting experimental studies in several very vital directions. One is the experimental verification of the general theory of relativity."

"But does it really need verification? In fact experiments proving that Einstein was correct have long since been performed ..."

"True in principle, if one can word it thusly, conceptually ... However, the quantitative conclusions of the GTR were able to be able to be confirmed at a relatively low precision level. One of the main experimental arguments in favor of GTR -- the curvature of light rays under the action of the sun's gravity field --

is well known. Detecting this deviation and measuring it has until recently been possible in rare cases during solar eclipses when, for the Earth observer, owing to the curvature of light rays, some stars prove to be somewhat shifted from their true position in the heavens. The idea of the experiment was proposed even by Einstein himself, and in 1919 it was possible to first measure this effect, although true, only approximately. Later, the best results of this experiment confirmed the quantitative relations of GTR to a precision of plus-minus 20 percent. But this is not adequate ..."

"Why?"

"If only because there are theories competing with GTR, such as, for example, the Brance-Dickey theory, accepting the conclusions of the theory of relatively, but predicting other quantitative manifestations of the relativistic effects. And this is not simply because some secondary coefficients are not in agreement. The competing theories represent differently many important details in the picture of the world formulated by Einstein. The last word, as always, belongs to experimentation -- a sufficiently exact quantitative verification of the effects of GTR. And it is precisely space technology that makes this verification possible."

"Can you tell us a little, please, on how this is being done ..."

"There are several experiments: some have already been conducted; others are being elaborated in detail, while still others are still in the planning stage and are being discussed. The main idea of many new experiments is that it is simplest to measure the lag in a ray owing to its curvature than this curvature itself. The measurements can be conducted not in the light, but in the radio range. From the point of view of physics, this does not matter -- both light and radio waves have the same electromagnetic nature.

"At first, the measurements were made with radar methods -- the additional lag, produced by curvature of a radio beam, in the impulse signal which was sent by an Earth radio transmitter to Mars, and, being reflected from it, returned -- was measured. The measurements naturally were taken at the moment when Mars, Sun and Earth were along the same line. In order to estimate all the experimental difficulties, one need only recall that when a light or radio beam travels from Mars to Earth past the Sun, all relativistic effects are equivalent to the deviation of this ray by only 10 km, at the time when the distance between the planets is about 350 million km! The trip of the radio pulse "there and back" will take a bit under an hour and here it is necessary to detect the additional lag in the signal of only several thousandths of a second. Delicate methods of radio technical measurements have made it possible in these experiments to confirm the quantitative conclusions of the GTR to a precision of up to 10%. The next step must be done when the deviation produced by the Sun in a radio beam sent to Earth from a spacecraft is measured."

"And what precision was obtained in this case? ..."

"In the program of our symposium there is a report by the famous specialists on the experimental verification of the GTR, professors at the Massachusetts Institute of Technology R. Rosenberg and J. Shapiro, on the latest results they obtained during the flight of Mariner 9 in an orbit around Mars. The speakers, unfortunately, did not come to the congress (they are completing the interpretation of the measurements), but Professor W. Rigley, in reading their paper, reported in a private conversation: it is already clear that the precision of the latest experiment is two percent. This is a very good and important result. Two percent, for example, is quite adequte in order to bury the theory of

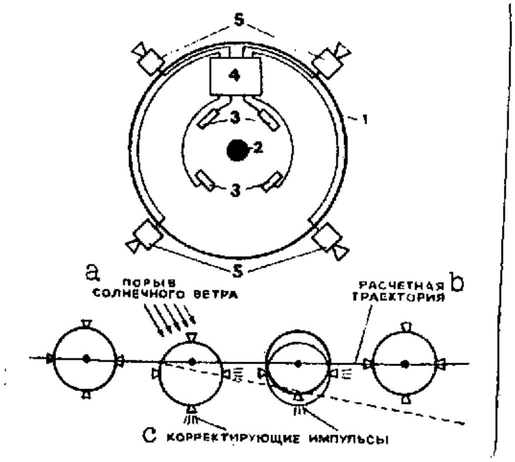
Sitting down to lunch does not mean abandoning discussion.

Brance-Dickey. However, judging from experiments which are now being prepared and discussed, two percent is far from the limit ..."

"How can this indicator be improved? And by how much?"

"Before answering, one must explain why in these experiments it is necessary for the spacecraft to rotate around Mars (or any other planet), and why we cannot /24 receive control signals from a craft that is in a free space closer to the Earth. The whole problem here is in the wind, in the solar wind. Streams of solar particles and radiation blow the craft, blow unevenly, speaking figuratively, toss it from side to side. In these conditions it is not possible to detect (even less so to a high precision!) the relativistic deviation of a radio beam by some 10 km. In order for the spacecraft not to blow, it is "coupled" to the large mass of a distant planet. For example, it is injected into the orbit of a Mars satellite. It is assumed that further improvements in this method will increase the precision of measurements by several tens of times.

"But there is also a fundamentally different approach: the use of spacecraft that will not be tossed by solar wind. The term "a craft free of downwash" is now one of the most fashionable; already there have appeared the actual spacecraft free of downwash ... and, as yet it is true, in Earth orbit. It is possible that even in the near future it will be found feasible to conduct experiments on testing the GTR, by receiving radio waves from an interplanetary station free of downwash and recording, as usual, their deviation by the Sun. It is assumed that in the experiments quantitative conclusions of the GTR will be verified to a precision of hundredths of a percent."



A satellite free of downwash and a scheme for stabilizing its orbit:

1. hull
2. "ball"
3. "ball" position sensors
4. electronic block of servo system
5. vernier motors

Ye. Rots (FRG). A priori error in the Sorel program. (illustration to paper)

Key: a. Gust of solar wind
b. Calculated trajectory
c. Correcting impulses

"What further experiments associated with the verification of the GTR is space technology capable of?"

"At our symposium, Candidate of Physico-Mathematical Sciences, N. Kolosnitsyn, spoke about his joint development, with K. Stanyukovich and V. Moskovkin, of an experiment to verify in this case not the consequences, but one of the main premises of the GTR -- the principle of equivalence, which as we know states that in the same gravity field all bodies are equally accelerated. Einstein, in justifying the principle of equivalence theoretically, at the same time knew well that the fundamental postulate must be verified with the greatest possible care. Over the past several decades, in various countries, investigators using different ground methods have verified the principle of equivalence and have confirmed its validity to a precision of the twelfth decimal place. N. Kolosnitsyn et al. proposes to advance even further, by measuring to a higher precision on board a spacecraft the rotation of an unusual dumbbell with respect to the Earth when the Sun is in different positions relative to the dumbbell-Earth system.

"An original method of verifying the quantitative relations of the GTR has been proposed by Professor M. Shirokov. There are no distant participants in his experiment, such as the Sun and an artificial Mars satellite. All the measurements are conducted on board an Earth spacecraft free of downwash."

Evidently the time has already come to explain, of course, in the most general outline how a spacecraft free of downwash is constructed. How can a spacecraft, this isolated speck divorced from all else resist the gusts of solar wind.

At first we note that from the standpoint of our engineering there is no problem here: low-power onboard jet engines easily correct the craft trajectory, compensate for the gusts of solar wind and thus, do not allow the craft to stray from its calculated path.

But how can the correcting [vernier] engines be controlled? How can the displacing forces be sensed, how can the invisible line along which the craft must move be held to? There can be no question about controlling the craft from Earth -- try, for example, from a distance of millions and tens of millions of kilometers of detecting the displacement of a craft by several angular seconds, which, incidentally, ultimately leads to a trajectory error of hundreds and thousands of kilometers.

After many years of investigation and development, a solution was found. Externally it appears quite simple. Imagine that in the center of the craft is a ball unconnected with anything else. With respect to the craft walls it is in weightlessness. At the very beginning of the path, together with the craft the ball receives the necessary acceleration, and now together and at the same time virtually independently from each other they fly along the calculated trajectory. The solar wind is an external force; it presses only against the spacecraft hull and only displaces it.

But the ball continues to fly along its path, virtually undeflected. If around the ball are placed position sensors, for example, capacitive or laser sensors, then during gusts of the solar wind they will instantaneously record the displacement of the sphere from the craft's center (more correctly put, the displacement of the craft relative to the sphere). On receiving a signal that this is happening, an onboard servo system determines the necessary correcting impulses and sends the appropriate commands to the jet vernier engines.

This system in some way resembles man, who in unfavorable weather constantly travels along the streets and only rarely adjusts his wind-blown hat. But this comparison should produce no illusions that stabilizing a craft is as easy and simple as adjusting one's hat when it is windy. A spacecraft free of downwash is an extremely complicated instrument. This complexity, it is true, is repaid many-fold by the high precision of measurements that can be made with this instrument ... Several of them /25
have already been discussed, and several more will be. We continue our conversation with Professor V. Braginskiy.

"You spoke about several important experimental corrections that space technology opens up for physicists. Verification of the GTR is one of them. What do you put in second place? In third place?"

"The answer to this question cannot, really, fail to be subjective. It strikes me as exceptionally important to set up experiments to detect gravity waves, this special form of matter that is predicted by the theory of relativity, but thus far not yet detected by anyone. Gravity waves must affect cosmic events of the scale as the collision of two stars or the flight of one star past another. In spite of the numerous attempts, it has not yet been possible to detect gravity waves with ground instruments specially designed for this purpose, including very advanced ones.

Today one can already propose a space experiment which will make it possible to leave the impasse. Its basis is two downwash-free spacecraft flying in the same direction at a not very great distance (1-5 million km) and linked with a radio system of measurement of the relative velocity (transmitter, receiver and a meter for measuring frequency change due to the Doppler effect). Calculations by specialists at Moscow University show that in this experiment, with a instrumental precision obtainable in principle, gravity fields can be detected.

"But not only is the actual possibility of this detection important. With time, this system of searching for sources of gravity waves will supply exceptionally vital information about events in the universe. Particular if, as proposed by Academician V. G. Ginzburg, space complexes will be set up for synchronous recording of radiations of different kinds -- X-ray, light, radio, gravity, gamma-rays and corpuscular streams.

"Already the first experiments on studying the universe with spacecraft have given truly sensational results. Such as, for example, the detection of several highly interesting sources of X-ray radiation, some of which can be "black holes." But, of course, we today are seeing on the very beginning. The powerful industry of scientific space research will considerably deepen our fundamental knowledge about the world around us."

There is a scientific problem over which mankind has been pondering for many millenia, but a realistic approach to its solution became possible only in our time, in the age of astronautics and electronics. This problem is the search for extraterrestrial civilizations. As follows from several probability estimates, they must exist somewhere in the measureless expanses of the universe (a comment on the "somewhere": the dimensions of the part of the universe known to us is 10 billion light years, and those of our galaxy -- 100,000 light years, the solar system -- 6 light hours, and the Earth -- 0.04 light sec. Without losing hope that brothers in reason will find us themselves (true there is the view that this has already been done, that we have already been found), some groups of researchers in the United States and the USSR are undertaking attempts to pick up radio signals that could be associated with activity of highly developed, thinking creatures.

One such effort was reported on at the congress.

Radiograms From "Aliens"!

L. Gindilis, N. Kardashov, V. Mirovskiy, V. Soglasnov, Ye. Spagensberg, and V. Etkin (USSR). "Search for Signals of Extra-terrestrial Civilization by the Method of Synchronous Reception." (abstract of paper)

Essentially, the method consists in receiving signals in the centimeter and decimeter waves (wavelengths -- 55-90 cm and 20-22 cm), and simultaneously at two points separated by a large distance -- by 3000 km in the first series of experiments. This wide dispersion precludes simultaneous reception at both points of signals of terrestrial origin -- the waves of the selected range propagate only along a distance of direct visibility and if interference appears in the region of one receiver, it will not reach the second.

In addition to different kinds of natural bursts of radio emission, signals of a clearly artificial origin -- even square-wave pulses -- were detected. Their careful analysis revealed the following: the source of the signals lies within the solar system. And since there are no other investigations in this area (in particular, with regular monitoring of the radio emission of

One of the participants in the discussion of the international orbital laboratory, physician Yu. Senkevich, having been in expeditions on the papyrus raft Ra, and now no longer a theoretician, but also a practitioner in the psychology of international crews.

planets), no civilization was detected, but it remained to conclude that signals from one of the Earth satellites, let us say telemetry signals, were picked up by accident.

The developed technique and equipment is being used in the following series of experiments.

The problems of establishing contact with extraterrestrial civilizations of course are absorbingly interesting (we do not know how everything is arranged there "somewhere," but on Earth with us, without healthy curiosity there would be neither science nor life itself), but still in the program of the congress relatively little attention was given to it. What can you do -- "it is a matter of time..."

Dr. A. Mutunayagam, a director of the division of jet engines of the Indian space center at Trivandrum, in a conversation with the Nauka i Zhizn' correspondent energetically recalls that there is

A Most Important Task for the Planet,

to which specialists in space technology must give their maximum time, energy, and funds.

"Let me ask you, Dr. M. Mutunayagam, first to tell us /26
something about the Indian space program in general ..."

A paper is presented by a person who has been in space himself. The theme of scientific research by pilot-cosmonaut G. Beregovoy is space flight safety.

"As early as 1962 the first rocket center was initiated in India in Tkhumba with launch facilities, tracking radar and plants producing research rockets and rocket fuel. During the first 10 years, 440 Rohini 125, 20 Rohini 100, five Centaur rockets and 30 weather rockets were built at this center. Regular launches are being made of research rockets, including joint launches with the Soviet Union, England, France and Japan. In 1974 India's third space center will go into operation at Scrikaricote, designed to launch satellites. In addition, it is planned to launch the first Indian satellite with a Soviet rocket from a Soviet launch complex. Development of our own four-stage rocket is being completed, which for the outset will be capable of placing into orbit a 40-kg satellite. A network of ground tracking stations is being enlarged."

"Everyone knows what a heavy legacy India acquired from colonialism, what complex economic problem face it. Is it desirable in these conditions to spent funds for space?"

"I am among the persons who believe that it is not only useful, but also necessary. A country that does not think of tomorrow is doomed. It is well known that today only two countries can effectively work in all areas of the space front -- the Soviet Union and the United States. In their actual affairs and capabilities they are far ahead of all others. But why is this? Because of the large population? Natural resources? Enormous territory? Of course, no! Everything is determined by the

A star that gives us life is our sun. Here it is photographed from space orbit by the X-ray telescope on Skylab.

scientific and industrial potential of these countries, and the successes in space became only a distinctive indicator of this potential. An indicator at which all the world looks. And further -- these successes proved to be a stimulus to scientific and technical progress.

"For India the possibility of sharply accelerating the solution of Earth problems, in particular, in agriculture, industry and in public health is linked with work in space technology, in spite of everything ..."

"What do you have in mind?"

"Public education, increasing the cultural level of the people, training of specialists. Isn't it really on this that success in all fields of human activity depends above all? India's population is nearly 550 million. And all need to be taught at different rungs on the ladder of learning. But where can one get the number of teachers for this?

"The only way out is space systems for educational and instructional television via satellites. Education through satellites is a task of vital importance not only for India, but also for many other countries.

"Public education, communications, meteorology, study of natural resources, monitoring the environment and television broadcasting, in my view, is already a sufficient list in order to appreciate why more and more countries are seeking possibilities of working in space technology, are beginning to launch spacecraft, and are beginning to move along the path onto which your country entered 16 years ago."

The path on which our country was the first to embark ...

Now for already a number of centuries many thousands of vessels have crossed the Atlantic, have cruised between America and Europe. One can scarcely keep count of all these voyages, or know the names of all the captains. Transatlantic industry does not deal in this. It is operating. But the name of the man who was first to sail a ship across the Ocean is known to every schoolchild -- history is able to liberally pay for daring, for the first steps into the unknown.

Sixteen years ago our country opened up the path into space for mankind with the launch of the first satellite. And already many times the planet has applauded our space "firsts" -- the first cosmonaut, the first Lunnik, the first flight around the Moon, the first interplanetary flight, the first orbital laboratory ...

From these unique experiments began the path of mankind to the present-day powerful industry of space research and flights.

The major successes of this industry lie still in the future, and they perhaps are destined to most strongly influence the life of people, our knowledge of the structure of the universe. But even today space industry, which is receiving enormous advance attention from society, is using all the capabilities in order to earn this attention, and is introducing increasingly greater contributions to solving everyday life, earthly problems.

This almost paramount feature of astronautics in our day is clearly reflected in the program, in the work and in the actual spirit of the XXIV International Astronautics Congress.